

OPTIMIZATION OF CYLINDRICAL GRINDING PARAMETER FOR THE HIGH  
PRODUCT QUALITY SUBJECT TO ROUNDNESS CONSTRAINT

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### **SUPERVISOR'S DECLARATION**

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Manufacturing Engineering.

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I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

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## ABSTRACT

In the manufacturing cylinder rod industry, final roundness of a product is very important to determine the products quality. Good roundness not only ensures good quality, but also reduces manufacturing costs. Final roundness is a important aspect of tolerance, it reduce installation time and reduce operating hours at the same time to reduce the overall cost. In this study, the main objective is to study the effect of work piece diameter, work speed and cutting depth of the roundness error in the process of cylindrical grinding by using outside cylindrical grinding machines. Roundness errors measure by using roundness measuring machine. The results of experimental analyze by using statistical methods with the help of DOE software. Based DOE method, the experiment was run by using the full factorial method and the results were analyzed using the Statistica software. The correlation for roundness error with the cutting parameters satisfies a reasonable degree of approximation. Depth of cut is the most significant parameter in affecting the roundness error work piece. The optimal parameters are, for work piece diameter is 18.71mm, for speed is 74.96rev/min and for depth of cut is 15.91 $\mu$ m.

## ABSTRAK

Dalam industri pembuatan rod silinder, kebulatan akhir sesuatu produk adalah sangat penting dalam menentukan mutu produk. Kebulatan yang baik bukan sahaja menjamin kualiti, malah mengurangkan kos pembuatan. Kebulatan akhir penting dalam aspek toleransi, ia mengurangkan masa pemasangan dan mengurangkan waktu operasi sekaligus dapat mengurangkan kos keseluruhan. Dalam kajian ini, tujuan utama adalah untuk mempelajari pengaruh diameter bahan kerja, kelajuan kerja dan kedalaman pemotongan terhadap kesalah kebulatan bahan kerja dalam proses menggiling berbentuk silinder dengan menggunakan mesin giling silinder. Kesalahan kebulatan dikira menggunakan mesin mengukur kebulatan. Hasil keputusan eksperimen dikaji menggunakan kaedah statistika dengan bantuan perisian DOE. Berdasarkan kaedah DOE, eksperimen yang dijalankan ialah menggunakan kaedah faktor penuh dan keputusan yang diperoleh dianalisis menggunakan perisian Statistica. Pengaruh kesalahan kebulatan dengan parameter pemotongan memenuhi tahap pendekatan yang sewajarnya. Kedalaman pemotongan merupakan parameter yang paling signifikan dalam mempengaruhi kesalahan kebulatan bahan kerja. Parameter yang optimum adalah, untuk diameter benda kerja ialah 18.71mm, untuk kelajuan kerja ialah 74.96rev/min dan untuk kedalaman potong ialah 15.91 $\mu$ m.

## TABLE OF CONTENT

	Page
<b>SUPERVISOR’S DECLARATION</b>	ii
<b>STUDENT’S DECLARATION</b>	iii
<b>DEDICATION</b>	iv
<b>ACKNOWLEDGEMENTS</b>	v
<b>ABSTRACT</b>	vi
<b>ABSTRAK</b>	vii
<b>TABLE OF CONTENTS</b>	viii
<b>LIST OF TABLES</b>	xiii
<b>LIST OF FIGURES</b>	xiv
<b>CHAPTER 1 INTRODUCTION</b>	
1.1 INTRODUCTION	1
1.1.1 Cylindrical Grinding is defined as having four essential actions	3
1.1.2 Reasons for Grinding	3
1.2 Problem Statement	3
1.3 Objective	4
1.4 Scope Of The Study	4
1.5 Project Background	4

## CHAPTER 2            LITERATURE REVIEW

2.1	INTRODUCTION	6
2.2	SURFACE ROUNDNESS	7
2.3	ROUNDNESS MEASURING METHOD	7
2.3.1	Diameter measurement	7
2.3.2	Vee-Block Method	8
2.3.3	Coordinate Measuring Machine (CMM)	9
2.3.4	Rotational Datum Method	9
2.4	CYLINDRICAL GRINDING MACHINE	9
2.4.1	Headstock	10
2.4.2	Grinding Wheel	10
2.4.3	Coolant System	11
2.5	TYPE OF CYLINDRICAL GRINDING	12
2.5.1	Outside diameter grinding	12
2.5.2	Inside diameter grinding	13
2.5.3	Centerless grinding	14
2.6	TYPES OF ABRASIVES	15
2.7	GRINDING WHEEL	16
2.8	GRINDING PROCESS	17
2.8.1	Speed of grinding wheel	17
2.8.1	Speed of work	17
2.8.1	Feed rate	17
2.8.1	Depth of cut	18
2.9	ROUNDNESS MEASURING MACHINE	18
2.9.1	Roundness Measuring Machine RANDCOM-31C Specification	19
2.10	AISI 1042 CARBON STEEL	21
2.11	BAND SAW	21
2.12	TURNING WITH LATHE MACHINE	22
2.12.1	Cutting parameters	23



2.12.2	Facing Operation	25
2.13	STATISTICA SOFTWARE	25
2.13.1	STATISTICA Features and Benefits	26
2.14	PREVIOUS REASEARCH	27
2.14.1	Prediction of Surface Roughness And Roundness Error In Cylindrical Grinding	27
2.14.2	Multi-Parameter Optimization and Control of the Cylindrical Grinding Process	28
2.14.3	Improvements In Out-Of-Roundness And Microhardness Of Inner Surfaces By Internal Ball Burnishing Process	29

### **CHAPTER 3            METHODOLOGY**

3.1	INTRODUCTION	31
3.2	EXPERIMENT DESIGN	32
3.2.1	Full Factorial Design	32
3.3	WORKPIECE PREPARATION	34
3.3.1	Work piece Cutting Process	34
3.3.2	Burr Discard Process	35
3.3.3	Turning Process	36
3.4	CYLINDRICAL GRINDING PROCESS	36
3.4.1	Aluminum Oxide Grinding Wheel	37
3.5	ROUNDNESS TEST	38
3.6	ANALYSIS OF RESULT	38

### **CHAPTER 4            RESULT AND DISCUSSION**

4.1	INTRODUCTION	41
4.2	EFFECT OF ROUNDNESS RESULT	41
4.2.1	Roundness Experiment Result	41
4.2.2	Analysis Result	43
4.2.3	Analysis of Variance (ANOVA)	51

**CHAPTER 5            CONCLUSION**

5.1	Introduction	57
5.2	Conclusion	54
5.3	Recommendation	55

<b>REFERENCES</b>	<b>57</b>
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**APPENDICES**

Appendix A	THE PLANNING OF STUDY	60
Appendix B	WORK PIECE PREPARATION	62
Appendix C	CYLINDRICAL GRINDING PROCESS	63
Appendix D	ROUNDNESS MEASURING PROCESS	64
Appendix E	ANALYSIS PROCESS BY USING STATISTICAL SOFTWARE	66
Appendix F	PROPERTIES OF AISI 1042	67
Appendix G	CHEMICAL COMPOSITION RESULT	68
Appendix H	FLOW CHART	69

## LIST OF TABLES

<b>Table No.</b>	<b>Title</b>	<b>Page</b>
2.1	Cutting Fluid	12
2.2	Description Type of Abrasives	15
2.3	Roundness Measuring Machine RANDCOM-31C Specification	19
2.4	Previous Research	30
3.1	Experiment and Result Table	33
3.2	Specification of S-300HB Band Saw Machine	35
3.3	ANOVA Table	39
4.1	Roundness Result	42
4.2	Effect Estimate	44
4.3	Regression Coefficient	50
4.4	Analysis of Variance (ANOVA)	51
A-1	Gantt Chart for Final Year Project 1	60
A-2	Gantt Chart for Final Year Project 2	61
F-1	AISI1042	67
F-2	AISI1042 Composition	67
F-3	AISI1042 Mechanical Properties	67
F-4	AISI1042 Thermal Properties	67

## LIST OF FIGURES

<b>Figure No.</b>	<b>Title</b>	<b>Page</b>
1.1	Grinding cycle with roughing, finishing and spark out stages	2
2.1	Example of a work piece with roundness error	7
2.2	Cylindrical Grinding Machine	10
2.3	Outside Grinding Process	13
2.4	Inside Grinding Process	13
2.5	Centerless Grinding Process	14
2.4	Cylindrical Grinding Wheel	16
2.5	Roundness Measuring Machine	19
2.6	Horizontal Band Saw Machine	22
2.7	Lathe Machine	23
2.8	Facing Process	25
3.1	Material Cutting Process	34
3.2	File	35
3.3	Lathe Machine	36
3.4	Wheel (Silicon Carbide)	37
3.5	Roundness Measuring Machine	38
4.1	A Work piece After Grinding Process with Different Depth of Cut	41
4.2	Three Work pieces After Grinding Process with Different Diameter	41
4.3	Graph Observed against Predicted Value	43
4.4a	Graph 2-Dimension for Cutting Speed Against Work piece Diameter	44
4.4b	Graph 3-Dimension for Cutting Speed Against Work piece Diameter	45

4.5a	Graph 2-Dimension for Depth of Cut Against Work piece Diameter	46
4.5b	Graph 3-Dimension for Depth of Cut Against Work piece Diameter	47
4.6a	Graph 2-Dimension for Depth of Cut Against Cutting Speed	48
4.6b	Graph 3-Dimension for Depth of Cut Against Cutting Speed	49
4.7	Graph Residual against Expected Normal	52
B-1	Raw Material Cutting Process	62
B-2	Turning Process	62
C-1	Cylindrical Grinding Setup	63
C-2	Cylindrical Grinding Process	63
D-1	Roundness Measuring Machine	64
D-2	Specimen Centering Process	65
D-3	Result of Roundness	65
E-1	Key-in The Data	66
E-2	Analysis Process	66
G-1	Chemical Composition Result	68
H-1	Flow chart for Final Year Project	69

## **CHAPTER 1**

### **INTRODUCTION**

#### **1.1 INTRODUCTION**

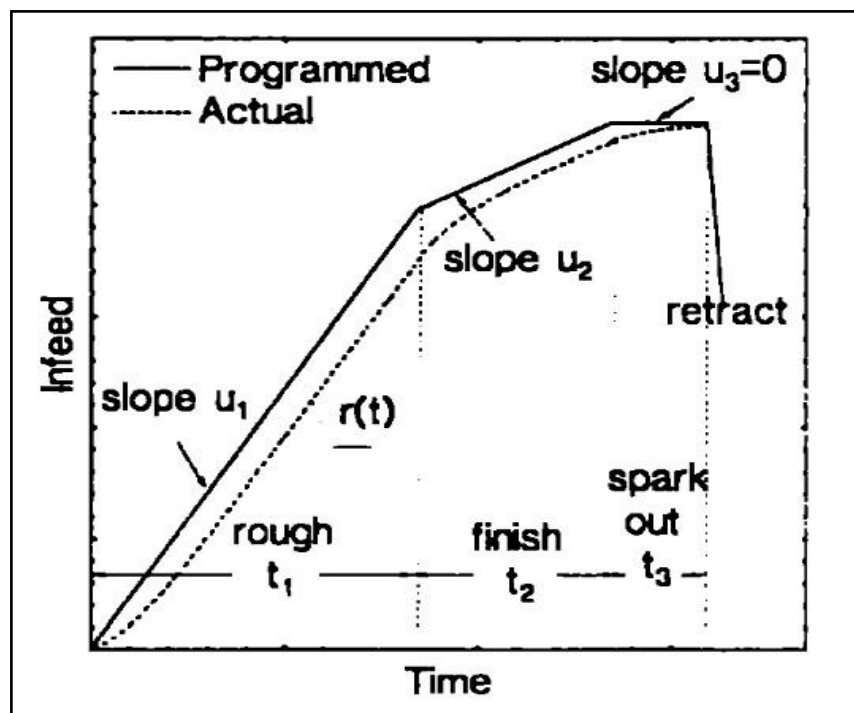
Grinding is a finishing process used to improve surface finish, abrade hard materials, and tighten the tolerance on flat and cylindrical surfaces by removing a small amount of material (Savington, 2009). Grinding is an essential process for final machining of components requiring smooth surfaces and precise tolerances.

According to Bianchi et al. (1999), the grinding process is known as one of the most complex tooling processes, due to the great number of variables involved, whereas such process should be employed in finishing operations, in which good final quality, low roundness errors of the piecework are expected, being that the reduction of the diametrical wear of grinding wheel should always be looked for to reduce the costs of the process. (Souza and Catai, 2004)

According to Malkin (1989), the grinding process requires a significant energy quantity for the material removal. Such energy, once transformed into heat, is concentrated within the cutting region. The high temperature may provide a situation in which the surface burning, the superficial heating and micro-structural transformations might occur, allowing the retempering of the material, since most grinding processes occur in tempered steels, with the formation of non-tempered martensite, providing undesirable and uncontrollable residual tensions, reducing the strength limit to the exhaustion of the tool component. Besides, the uncontrolled expansion and retraction of the mechanical piece during the grinding operation are the most outstanding cause of roundness errors.

The cylindrical grinder is a type of grinding machine used to shape the outside of an object. The cylindrical grinder can work on a variety of shapes. However, the object must have a central axis of rotation. This includes but is not limited to such shapes as a cylinder, an ellipse, a cam, or a crankshaft. (De Souza and Catai, 2004)

Grinding is a costly machining process which should be utilized under optimal conditions. The usual optimization objective in cylindrical plunge grinding is to minimize production time while satisfying work piece quality constraints. The time for a typical cycle (figure 1.1) includes  $t$ ; for roughing with a fast programmed infeed velocity  $u_1$ , and  $t_2$  for finishing with a slower velocity  $u_2$ , and  $t_3$  for spark-out ( $u_3=0$ ). Additional production time is required for wheel dressing, part loading/unloading, set-up, and wheel change. (Xiao and Malkin, 1996)



**Figure 1.1:** Grinding cycle with roughing, finishing and spark out stages

Source: Xiao and Malkin (1996)

### **1.1.1 Cylindrical Grinding is defined as having four essential actions (Walker and John, 2004)**

- i. The work (object) must be constantly rotating
- ii. The grinding wheel must be constantly rotating
- iii. The grinding wheel is fed towards and away from the work
- iv. Either the work or the grinding wheel is traversed with the respect to the other.

### **1.1.2 Reasons for Grinding**

Reasons for grinding are:

- i. The material is too hard to be machined economically. The material may have been hardened in order to produce a low-wear finish, such as that in a bearing raceway. (Richard and John, 2002)
- ii. Tolerances required preclude machining. Cylindrical grinder can produce tolerances of 0.0002 mm with extremely fine surface finishes. (Walker and John, 2004)
- iii. Machining removes excessive material.

## **1.2 PROBLEM STATEMENT**

Establishment of cylindrical grinding machine parameter has been confronted a problem in manufacturing industries for nearly a century and is still the subject of many studies. In industrial, high quality surface finish of cylinder product is important. Roundness is a part of surface finish quality. In industry, rod or cylinder product is an important product. Many products want high precision of roundness. The examples rod uses in industrial are automotive production, machine production and medical product production.

Surface roundness plays an important role on the required tolerance and fit especially during part assembly. Optimization parameters of machine to make good quality for surface roundness are of great concern in manufacturing environments,



where economic of machining operation plays a key role in competitiveness in the market. The optimization parameters can produce maximize production rate.

Student has a problem in attempt to identify the optimum of parameter cylindrical grinding process by use cylindrical grinding machine. Parameters that student must identify for roundness effect are diameter of work piece, cutting speed and depth of cut. Other parameters of cylindrical grinding machine are constant. The quality that study is subject to roundness constrain.

### **1.3 OBJECTIVE OF STUDY**

The objectives of these studies are:

- i. To determine roundness error of cylindrical grinding via experiment
- ii. To determine optimum cylindrical grinding process parameters

### **1.4 SCOPE OF THE STUDY**

The scopes of this project are:

- i. Use carbon steel to run cylindrical grinding process
- ii. Use aluminum oxide grinding wheel in cylindrical grinding process
- iii. Use roundness measuring machine to measure roundness of work piece
- iv. Determine optimum values of parameters there are diameter, speed and depth of cut for cylindrical grinding machine.
- v. The experiments and analysis with software prove the exactitude of optimum parameters.

### **1.5 PROJECT BACKGROUND**

In order to achieve the objective of this project, there is some guideline need to be understood. Chapter 1 discussed about of the scope, objective and problem statement of this project. Chapter 2 discussed more about literature review in which discusses overall about case study. Methodology of this study had been discussed on chapter 3 in which the methods and equipment that need to be apply in this project.

Chapter 4 shows the experiment's data or result of experiment. The results were analysis by using statistic software and the result is discussed. Lastly, chapter 5 is to make conclusion and recommendation for the experiment.

## **CHAPTER 2**

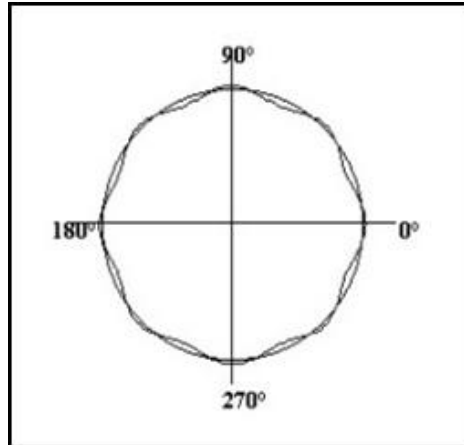
### **LITERATURE REVIEW**

#### **2.1 INTRODUCTION**

This chapter discussed about the cylindrical grinding process, cylindrical grinding parameter and the previous study that involved the optimization technique. Here, the optimization technique, full factorial method is review to get fully understanding before applied to the study.

According to Shaw (1994), one single work piece is never perfectly cylindrical, since all work pieces might show roundness errors, which are the main causes for such non-perfect cylindrical situation. The roundness error may be understood as any divergence between the built work piece and the work piece theoretically required with specified tolerance (Jedrzejewski and Modrzycki, 1997), whereas the amount of errors in a machine expresses a measurement of its accuracy. (De Souza and Catai, 2004)

From the type of errors usually found in a work piece, the roundness error (Figure 2.1), according to ASME (1982), the one that occurs when it's opposite radiuses are different at any position from the surface of the work piece. They are present in the cylindrical work piece, which passed through some manufacturing stage; many of them ready to be used.



**Figure 2.1:** Example of a work piece with roundness error

Source: Taylor-Hobson (2001)

## **2.2 SURFACE ROUNDNESS**

One of the most important fundamental forms for engineering components is the circular cross-section. Circular forms arise in many applications, particularly in bearing surfaces.

The measurement of out-of-roundness (usually referred to simply as "roundness") is an extremely important assessment. For example, a rotational bearing whose components are not accurately round will tend to be noisy and is likely to fail prematurely. Accurate roundness measurement is therefore vital to ensure correct function of such parts.

## **2.3 ROUNDNESS MEASURING METHOD**

### **2.3.1 Diameter measurement**

Perhaps the first and simplest approach to gauging the roundness of a component is to measure the consistency of its diameter at a number of different orientations.

This is often done in-process for checking machine setup and can be adequate for assessing a component where the roundness is a cosmetic, rather than functional, requirement. It can be functionally relevant of course, and a good example of this is the UK fifty-pence piece. One of the requirements for the coin is that it is able to be used in a coin-operated slot machine. The design as shown works very well in this application as it has a constant diameter. However it is clearly evident that the coin is not round.

At this stage it is useful to look at the ISO definition of roundness. Roundness is defined in ISO 1101 as the separation of two concentric circles that just enclose the circular section of interest. It is clear that measurement of diameter as shown above will not yield the roundness of the component in accordance with this definition.

### **2.3.2 Vee-Block Method**

Vee-block method that is the method that place the part in a vee-block and rotate it in contact with a dial gauge or similar indicator. This is essentially a three-point method rather than the two-point method above. If the part is truly round, with negligible irregularity, the pointer of the gauge will not move.

Errors in the form will cause the dial indicator to show a reading, however the part will also move up and down as the irregularities contact the vee-block. Moreover, in the case of a shaft, the contact with the vee-block is not restricted to the plane being measured. This means that irregularities of the component along its length will affect the dial indicator reading.

However the three-point method is applied, it will always suffer from the limitation that the results may vary according to the vee angle and the spacing of the irregularities. (Mike, 2007)

### **2.3.3 Coordinate Measuring Machine (CMM)**

Another way to measure roundness is to use a coordinate measuring machine (CMM). A standard CMM has three accurate, orthogonal axes and is equipped with a touch-trigger probe. The probe is brought into contact with the component being measured and its position is recorded. A number of points are taken around the component and these are then combined in a computer to calculate the roundness of the component.

Typically the number of data points is very small because of the time taken to collect them. As a result the accuracy of such measurements is compromised. (Mike, 2007)

### **2.3.4 Rotational Datum Method**

The most accurate method for determining roundness of a component is to measure the variation of radius from an accurate rotational datum using a scanning probe (one that remains in contact with the surface and collects a high-density of data points). A circle can then be fitted to this data and the roundness calculated from knowledge of the component centre. (Mike, 2007)

## **2.4 CYLINDRICAL GRINDING MACHINE**

Cylindrical grinding is used to grind the external or internal diameter of rigidly supported and rotating work piece. Although the term cylindrical grinding may also be applied to centerless grinding, it generally refers to work which is ground in a chuck or between supporting centers. Cylindrical grinders can be used to grind all types of hard or soft work pieces to a high degree of accuracy and very-fine surface finishes. (Youssef and Helmi, 2008). There are few parts of cylindrical grinding.



**Figure 2.2:** Cylindrical Grinding Machine

Source: First Machinery (2010)

#### **2.4.1 Headstock**

The headstock is mounted on the left end of the table and contains a motor for rotating the work. A dead center is mounted in the headstock spindle. When work is mounted between centers, it is rotated on two dead centers. (Youssef and Helmi, 2008)

#### **2.4.2 Grinding Wheel**

Grinding wheel is the most important products made from abrasives, are composed of abrasive material held together with a suitable bond. The basic functions of grinding wheels in a machine shop are make generation of cylindrical, flat and curve surface, to removal of stock, produce high finished surfaces, as cutting-off operations and make sharp edges and points production.

For grinding wheel function properly, they must be hard and tough. The material components of grinding wheel are abrasive grain and the bond. That must be considered in grinding wheel manufacture and selection. (Hassan, 2007)

Grinding wheels use several types of abrasive grains. Aluminum oxide, the most common industrial mineral in use today, is used either individually or with other materials to form ceramic grains. Silicon carbide, a synthetic abrasive that is harder than aluminum oxide, is typically used with nonferrous materials such as brass, aluminum, and titanium. Alumina-zirconia grains fuse aluminum oxide and zirconium oxide and are used to improve grinding performance on materials such as stainless steel. Synthetic diamond superabrasives are used for grinding nonferrous metals, ceramics, glass, stone, and building materials. Cubic boron nitride (CBN), another type of superabrasive, provides superior grinding performance on carbon and alloy steels. CBN is second only to diamond in terms of hardness.

Crushed tungsten carbide grits are used in metal-bonded products to abrade tough materials such as composites, fiberglass, reinforced plastics, and rubber. (Malkin and Cook, 1971)

### **2.4.3 Coolant System**

Coolant or lubrication is essential in metal-cutting operation to reduce the heat and friction created by the deformation of metal and the chip sliding along the chip-tool interface. This heat and friction cause metal to adhere to the tool's cutting edge and causing the wheel to break down. The finishing results will poor and inaccurate work. (Hassan El-Hofy, 2007)